Calculating credits for bioretention

Warning: Models are often selected to calculate credits. The model selected depends on your objectives. For compliance with the Construction Stormwater permit, the model must be based on the assumption that an instantaneous volume is captured by the BMP.

Green Infrastructure: Bioretention practices can be an important tool for retention and detention of stormwater runoff. Because they utilize vegetation, bioretention practices provide additional benefits, including cleaner air, carbon sequestration, improved biological habitat, and aesthetic value.

Recommended pollutant removal efficiencies, in percent, for biofiltration BMPs. Sources (http://stormwater.pca.state.mn.us/index.php/Information_on_pollutant_removal_by_BMPs#References). NOTE: removal efficiencies are 100 percent for water that is infiltrated.

TSS=total suspended solids; TP=total phosphorus; PP=particulate phosphorus; DP=dissolved phosphorus; TN=total nitrogen

TSS	TP	PP	DP	TN	Metals	Bacteria	Hydrocarbons
85	link to table (http://stormwater.pca.state.mn.us/index.php/Phosphorus_credits_for_bioretention_systems_with_an_underdrain)	link to table (http://stormwater.pca.state.mn.us/index.php/Phosphorus_credits_for_bioretention_systems_with_an_underdrain)	link to table (http://stormwater.pca.state.mn.us/index.php/Phosphorus_credits_for_bioretention_systems_with_an_underdrain)	50	35	95	80

Credit (http://stormwater.pca.state.mn.us/index.php/Overview_of_stormwater_credits) refers to the quantity of stormwater or pollutant reduction achieved either by an individual Best Management Practice (BMP) or cumulatively with multiple BMPs. Stormwater credits are a tool for local stormwater authorities who are interested in

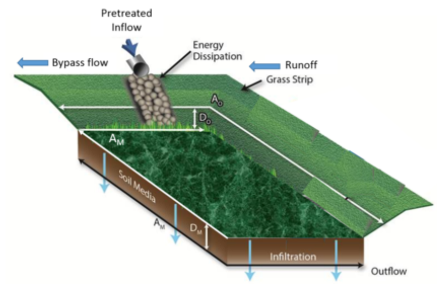
- providing incentives to site developers to encourage the preservation of natural areas and the reduction of the volume of stormwater runoff being conveyed to a best management practice (BMP);
- complying with permit requirements, including antidegradation (see [1] (http://stormwater.pca.state.mn.us/index.php/Construction_stormwater_permit); [2] (http://stormwater.pca.state.mn.us/index.php/MS4_General_Permit));
- meeting the MIDS performance goal (http://stormwater.pca.state.mn.us/index.php/Performance_goals_for_new_development,_re-development_and_linear_projects); or
- meeting or complying with water quality objectives, including Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs).

This page provides a discussion of how bioretention practices can achieve stormwater credits. Bioretention systems with and without underdrains are both discussed, with separate sections for each type of system as appropriate. In this discussion, bioretention systems with an underdrain are called biofiltration systems, while bioretention systems with no underdrain are called bioinfiltration systems.

Contents

Overview

Bioretention is a terrestrial-based (up-land as opposed to wetland) water quality and water quantity control process. Bioretention consists of an engineered soil media layer designed to treat stormwater runoff via filtration through plant and soil media, evapotranspiration from plants, or through infiltration into underlying soil. Pretreatment is REQUIRED for all bioretention facilities to settle particulates before entering the BMP. Bioretention practices may be built with or without an underdrain. Other common components of bioretention systems may include a stone aggregate layer to allow for increased retention storage and an impermeable liner on the bottom or sides of the facility if located near buildings, subgrade utilities, or in karst formations. Bioretention is a versatile stormwater treatment method applicable to all types of settings such as landscaping islands, cul-de-sacs, parking lot margins, commercial setbacks, open space, rooftop drainage, and streetscapes.

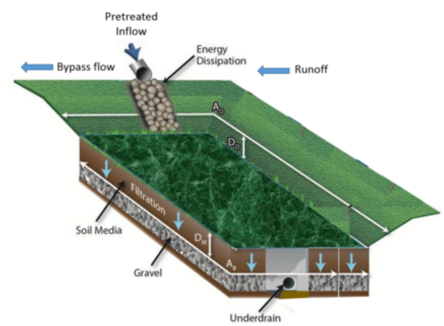


Schematic illustrating the components and processes for a bioinfiltration system.

Systems with no underdrain are called bioinfiltration, while those with an underdrain are called biofiltration. Biofiltration, commonly termed bioretention (http://stormwater.pca.state.mn.us/index.php/Bioretention) with underdrains, is primarily a stormwater quality control practice. Some water quantity reduction can be achieved through infiltration below the underdrain, particularly if the underdrain is raised above the bottom of the BMP, and through evapotranspiration. Biofiltration includes an underdrain layer to collect the filtered runoff for downstream discharge.

See Bioretention terminology for a discussion of different types of bioretention systems. Although tree trenches and tree boxes are a form of bioretention, they are discussed separately in this manual (http://stormwater.pca.state.mn.us/index.php/Calculating_credits_for_tree_trenches_and_tree_boxes).

Warning: The Construction Stormwater permit (http://stormwater.pca.state.mn.us/index.php/III._STORMWATER_DISCHARGE_DESIGN_REQUIREMENTS#III.D._PERMANENT_STORMWATER_MANAGEMENT_SYSTEM) REQUIRES pretreatment for bioretention practices



Schematic illustrating the components and processes for a biofiltration system.

Pollutant removal mechanisms

Bioretention practices have one of the highest nutrient and pollutant removal efficiencies of any BMP (Mid-America Regional Council (http://www.marc.org/Environment/Water-Resources/Local-Government-Resources/Stormwater-Best-Management-Practices) and American Public Works Association Manual of Best Management Practice BMPs for Stormwater Quality (https://www.leawood.org/public%20works/PDF/APWA%20BMP%20Manual.pdf), 2012). Bioretention provides pollutant removal and volume reduction through filtration, evaporation, infiltration, transpiration, biological and microbiological uptake, and soil adsorption; the extent of these benefits is highly dependent on site specific conditions and design. In addition to phosphorus and total suspended solids (TSS), which are discussed in greater detail below, bioretention treats a wide variety of other pollutants.

Removal of phosphorus is dependent on the engineered media. Media mixes with high organic matter content typically leach phosphorus and can therefore contribute to water quality degradation. The Manual provides a detailed discussion of media mixes, including information on phosphorus retention.

Location in the treatment train

Stormwater treatment trains are multiple BMPs that work together to minimize the volume of stormwater runoff, remove pollutants, and reduce the rate of stormwater runoff being discharged to Minnesota wetlands, lakes and streams. Bioretention facilities are typically located in upland areas of the stormwater treatment train, controlling stormwater runoff close to the source.

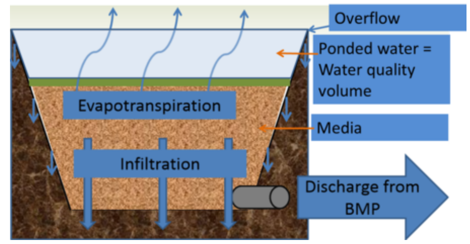
Methodology for calculating credits

This section describes the basic concepts and equations used to calculate credits for volume, Total Suspended Solids (TSS) and Total Phosphorus (TP). Specific methods for calculating credits are discussed later in this article.

Bioinfiltration practices generate credits for volume, TSS, and TP. Biofiltration practices do not substantially reduce the volume of runoff but may qualify for a partial volume credit as a result of evapotranspiration, infiltration occurring through the sidewalls above the underdrain, and infiltration below the underdrain piping. Bioretention practices are effective at reducing concentrations of other pollutants including nitrogen, metals, bacteria, and hydrocarbons. This article does not provide information on calculating credits for pollutants other than TSS and TP, but references are provided that may be useful for calculating credits for other pollutants.

Assumptions and approach

In developing the credit calculations, it is assumed the bioretention practice is properly designed, constructed, and maintained in accordance with the Minnesota Stormwater Manual. If any of these assumptions is not valid, the BMP may not qualify for credits or credits should be reduced based on reduced ability of the BMP to achieve volume or pollutant reductions. For guidance on design, construction, and maintenance, see the appropriate article within the bioretention section of the Manual.



Schematic illustrating the water quality volume (V_{WQ}) for a bioretention BMP. The V_{WQ} equals the volume of water ponded above the media and below the overflow point in the BMP. The schematic illustrates other processes occurring within the bioretention system. In this example, an underdrain is located at the bottom of the practice.

Warning: Pre-treatment is required for all bioretention practices

In the following discussion, the water quality volume (V_{WQ}) is delivered instantaneously to the BMP. The V_{WQ} is stored as water ponded above the filter media and below the overflow point in the BMP. The V_{WQ} can vary depending on the stormwater management objective(s). For construction stormwater, V_{WQ} is 1 inch off new impervious surface. For MIDS, V_{WQ} is 1.1 inches.

In reality, some water will infiltrate through the bottom and sidewalls of the BMP as a rain event proceeds. The instantaneous volume method therefore may underestimate actual volume and pollutant losses.

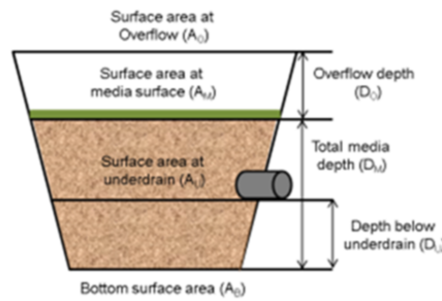
Volume credit calculations - no underdrain

Volume credits are calculated based on the capacity of the BMP and its ability to permanently remove stormwater runoff via infiltration into the underlying soil from the existing stormwater collection system. These credits are assumed to be instantaneous values entirely based on the capacity of the BMP to capture, store, and transmit water in any storm event. Because the volume is calculated as an instantaneous volume, the water quality volume (V_{WQ}) is assumed to pond below the overflow elevation and above the bioretention media. This entire volume is assumed to infiltrate through the bottom of the BMP. The volume credit (V_{inf_b}) for infiltration through the bottom of the BMP into the underlying soil, in cubic feet, is given by

$$V_{inf_b} = D_o \left(A_O + A_M\right) / 2$$

where

- A_O is the overflow surface area of the bioretention system, in square feet;
- A_M is the area at the surface of the media, in square feet; and
- D_O is the ponded depth with the BMP, in feet.



Schematic illustrating terms and dimensions used for volume and pollutant calculations.

Some of the V_{WQ} will be lost to evapotranspiration rather than all being lost to infiltration. In terms of a water quantity credit, this differentiation is unimportant, but it may be important if attempting to calculate actual infiltration into the underlying soil.

The annual volume captured and infiltrated by the BMP can be determined with appropriate modeling tools, including the MIDS calculator. Example values are shown below for a scenario using the MIDS calculator. For example, a permeable pavement system designed to capture 1 inch of runoff from impervious surfaces will capture 89 percent of annual runoff from a site with B (SM) soils.

Annual volume, expressed as a percent of annual runoff, treated by a BMP as a function of soil and water quality volume. See footnote[1] for how these were determined.
Link to this table

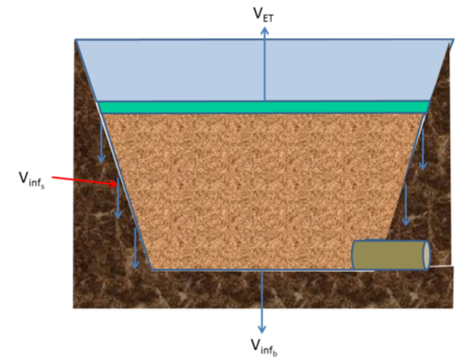
Soil	**Water quality volume (V_{WQ}) (inches)**				
	0.5	**0.75**	**1.00**	**1.25**	**1.50**
A (GW)	84	92	96	98	99
A (SP)	75	86	92	95	97
B (SM)	68	81	89	93	95
B (MH)	65	78	86	91	94
C	63	76	85	90	93

[1]Values were determined using the MIDS calculator. BMPs were sized to exactly meet the water quality volume for a 2 acre site with 1 acre of impervious, 1 acre of forested land, and annual rainfall of 31.9 inches.

Volume credit calculations - underdrain

Volume credits for biofiltration are available only if the BMP permanently removes a portion of the stormwater runoff via infiltration through sidewalls or beneath the underdrain piping, or through evapotranspiration. These credits are assumed to be instantaneous values based on the design capacity of the BMP for a specific storm event. Instantaneous volume reduction, also termed event based volume reduction, can be converted to annual volume

reduction percentages using the MIDS calculator (http://stormwater.pca.state.mn.us/index.php/Performance_curves_for_MIDS_calculator) or other appropriate modeling tools.



Schematic illustrating the different water loss terms for a biofiltration BMP with an underdrain at the bottom.

Volume credits for biofiltration basins with underdrains are calculated by a combination of infiltration through the unlined sides and bottom of the basin, the volume loss through evapotranspiration (ET), and the retention volume below the underdrain, if applicable (this is based on the assumption that this stored water will infiltrate into the underlying soil). The main design variables impacting the volume credits include whether the underdrain is elevated above the native soils and if an impermeable liner on the sides or bottom of the basin is used. Other design variables include surface area at overflow, media top surface area, underdrain location, and basin bottom locations, total depth of media, soil water holding capacity and media porosity, and infiltration rate of underlying soils.

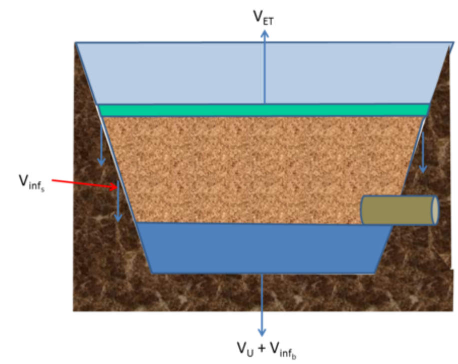
Information: For the following equations, units most commonly used in practice are given and unit correction factors are based on those units

The volume credit (V) for biofiltration basins with underdrains, in cubic feet, is given by

$$V = V_{inf_B} + V_{inf_s} + V_{ET} + V_U$$

where:

- V_{inf_b} = volume of infiltration through the bottom of the basin (cubic feet);
- V_{inf_s} = volume of infiltration through the sides of the basin (cubic feet);
- V_{ET} = volume reduction due to evapotranspiration (cubic feet); and
- V_U = volume of water stored beneath the underdrain that will infiltrate into the underlying soil (cubic feet).



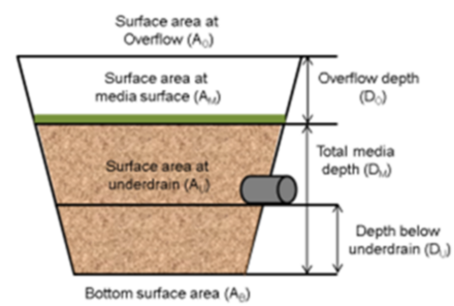
Schematic illustrating the different water loss terms for a biofiltration BMP with a raised underdrain.

Volume credits for infiltration through the bottom of the basin (V_{inf_b}) are accounted for only if the bottom of the basin is not lined. As long as water continues to draw down, some infiltration will occur through the bottom of the BMP. However, it is assumed that when an underdrain is included in the installation, the majority of water will be filtered through the media and exit through the underdrain. Because of this, the drawdown time is likely to be short. Volume credit for infiltration through the bottom of the basin is given by

$$V_{inf_B} = A_B \; DDT \; I_R/12$$

where

- I_R = design infiltration rate of underlying soil (inches per hour);
- A_B = surface area at the bottom of the basin (square feet); and
- DDT = drawdown time for ponded water (hours).



Schematic illustrating terms and dimensions used for volume and pollutant calculations.

Information: The MIDS calculator assigns a default value of 0.06 inches per hour, equivalent to a D soil, to I_R. This is based on the assumption that most water will drain to the underdrain, but that some loss to underlying soil will occur. A conservative approach assuming a D soil was thus chosen.

The drawdown time is typically a maximum of 48 hours, which is designed to be protective of plants grown in the media. The Construction Stormwater permit (http://stormwater.pca.state.mn.us/index.php/Construction_stormwater_permit) requires drawdown within 48 hours and recommends 24 hours when discharges are to a trout stream. With a properly functioning underdrain, the drawdown time is likely to be considerably less than 48 hours.

Volume credit for infiltration through the sides of the basin is accounted for only if the sides of the basin are not lined with an impermeable liner. Volume credit for infiltration through the sides of the basin is given by

$$V_{inf_s} = (A_O - A_U) \; DDT \; I_R/12$$

where

- A_O = the surface area at the overflow (square feet); and
- A_U = the surface area at the underdrain (square feet).

Information: The MIDS calculator assigns a default value of 0.06 inches per hour, equivalent to a D soil, to I_R. This is based on the assumption that most water will drain to the underdrain, but that some loss to underlying soil will occur. A conservative approach assuming a D soil was thus chosen.

This equation assumes water will infiltrate through the entire sideslope area during the period when water is being drawn down. This is not the case, however, since the water level will decline in the BMP. The MIDS calculator assumes a linear drop in water level and thus divides the right hand term in the above equation by 2.

Volume credit for media storage capacity below the underdrain (V_U) is accounted for only if the underdrain is elevated above the native soils. Volume credit for media storage capacity below the underdrain is given by

$$V_U = (n - FC)\ D_U\ (A_U + A_B)/2$$

where

A_B = surface area at the bottom of the media (square feet);
n = media porosity (cubic feet per cubic foot);
FC is the field capacity of the soil, in cubic feet per cubic foot; and
D_U = the depth of media below the underdrain (feet).

This is an instantaneous volume. This will somewhat overestimate actual storage when the majority of water is being captured by the underdrains. This equation assumes water between the soil porosity and field capacity (http://stormwater.pca.state.mn.us/index.php/Soil_water_storage_properties) will infiltrate into the underlying soil.

The volume of water lost through ET is assumed to be the smaller of two calculated values: potential ET and measured ET. Potential ET (ET_{pot}) is equal to the amount of water stored in the basin between field capacity and the wilting point (http://stormwater.pca.state.mn.us/index.php/Soil_water_storage_properties). Measured ET (ET_{mea}) is the amount of water lost to ET as measured using available data and is assumed to be 0.2 inches/day. ET_{mea} is converted to ET by multiplying by a factor of 0.5. ET is considered to occur over a period equal to the drawdown time of the basin. Volume credit for evapotranspiration is given by the lesser of

$$ET_{mea} = (0.2/12)\ A\ 0.5\ t\ \ ET_{pot} = D\ A\ C_S$$

where

t = time over which ET is occurring (days);
D = depth being considered (feet);
A = area being considered (square feet); and
C_S = soil water available for ET, generally assumed to be the water between field capacity and wilting point.

ET is likely to be greater if one or more trees is planted in the biofiltration basin. Planting a tree in a biofiltration system is HIGHLY RECOMMENDED. The MIDS calculator increases the above ET credit by a factor of 3 when a tree is planted in the bioretention basin.

Provided soil water content is greater than the wilting point, ET will continually occur during the non-frozen period. However, because the above volume calculations are event based, t will be equal to the time between rain events. In the MIDS calculator, a value of 3 days is used because this is the average number of days between precipitation events. ET will occur over the entire media depth. D may therefore be set equal to the media depth (D_M). In this case, the value for A would be the average area through the entire depth of the media. The MIDS calculator limits ET to the area above the underdrain. If infiltration is being computed through the bottom and sidewalls of the basin, then C_S would be field capacity minus the wilting point of soils (cubic feet per cubic foot) since water above the field capacity would infiltrate (or go to an underdrain).

The volume of water passing through underdrains can be determined by subtracting the volume loss (V) from the volume of water instantaneously captured by the BMP. No volume reduction credit is given for filtered stormwater that exits through the underdrain, but the volume of filtered water can be used in the calculation of pollutant removal credits through filtration.

The volume reduction credit (V) can be converted to an annual volume if desired. This conversion can be generated using the MIDS calculator or other appropriate modeling techniques. The MIDS calculator obtains the percentage annual volume reduction through performance curves (http://stormwater.pca.state.mn.us/index.php/Performance_curves_for_MIDS_calculator) developed from multiple modeling scenarios using the volume reduction capacity for biofiltration, the infiltration rate of the underlying soils, and the contributing watershed size and imperviousness.

Total suspended solids credit calculations

TSS reduction credits correspond with volume reduction through infiltration and filtration of water captured by the biofiltration basin and are given by

$$M_{TSS} = M_{TSS_i} + M_{TSS_f}$$

where

M_{TSS} = TSS removal (pounds);
M_{TSS_i} = TSS removal from infiltrated water (pounds); and
M_{TSS_f} = TSS removal from filtered water (pounds).

Pollutant removal for infiltrated water is assumed to be 100 percent. The event-based mass of pollutant removed through infiltration, in pounds, is given by

- biofiltration - $M_{TSS_i} = 0.0000624\ (V_{inf_b} + V_{inf_s} + V_U)\ EMC_{TSS}$
- bioinfiltration - $M_{TSS_i} = 0.0000624\ V_{WQ}\ EMC_{TSS}$

where

EMC_{TSS} is the event mean TSS concentration in runoff water entering the BMP (milligrams per liter).

The EMC_{TSS} entering the BMP is a function of the contributing land use and treatment by upstream tributary BMPs. For more information on EMC values for TSS, link here (http://stormwater.pca.state.mn.us/index.php/Total_Suspended_Solids_%28TSS%29_in_stormwater) or here (https://stormwater.pca.state.mn.us/index.php?title=Event_mean_concentrations_by_land_use). If there is no underdrain, the water quality volume (V_{WQ}) is used in this calculation.

Removal for the filtered portion is less than 100 percent. The event-based mass of pollutant removed through filtration, in pounds, is given by

$$M_{TSS_f} = 0.0000624\ (V_{total} - (V_{inf_b} + V_{inf_s} + V_U))\ EMC_{TSS}\ R_{TSS}$$

where

V_{total} is the total volume of water captured by the BMP (cubic feet); and
R_{TSS} is the TSS pollutant removal percentage for filtered runoff.

The Stormwater Manual (http://stormwater.pca.state.mn.us/index.php/Pollutant_removal_percentages_for_bioretention_BMPs) provides a recommended value for R_{TSS} of 0.85 (85 percent) removal for filtered water, while the MIDS calculator provides a value of 0.65 (65 percent). Alternate justified percentages for TSS removal can be used if proven to be applicable to the BMP design.

The above calculations may be applied on an event or annual basis and are given by

$$M_{TSS_f} = 2.72\ F\ V_{F_{annual}}\ EMC_{TSS}\ R_{TSS}$$

where

F is the fraction of annual volume filtered through the BMP; and
V_{annual} is the annual volume treated by the BMP, in acre-feet.

Phosphorus credit calculations

Total phosphorus (TP) reduction credits correspond with volume reduction through infiltration and filtration of water captured by the biofiltration basin and are given by

$$M_{TP} = M_{TP_i} + M_{TP_f}$$

where

- M_{TP} = TP removal (pounds);
- M_{TP_i} = TP removal from infiltrated water (pounds); and
- M_{TP_f} = TP removal from filtered water (pounds).

Pollutant removal for infiltrated water is assumed to be 100 percent. The mass of pollutant removed through infiltration, in pounds, is given by

- biofiltration - $M_{TP_i} = 0.0000624\ (V_{inf_b} + V_{inf_s} + V_U)\ EMC_{TP}$
- bioinfiltration - $M_{TP_i} = 0.0000624\ V_{WQ}\ EMC_{TP}$

where

- EMC_{TP} is the event mean TP concentration in runoff water entering the BMP (milligrams per liter).

The EMC_{TP} (https://stormwater.pca.state.mn.us/index.php?title=Event_mean_concentrations_by_land_use) entering the BMP is a function of the contributing land use and treatment by upstream tributary BMPs.

The filtration credit for TP (http://stormwater.pca.state.mn.us/index.php/Phosphorus_credits_for_bioretention_systems_with_an_underdrain) in bioretention with underdrains assumes removal rates based on the soil media mix (http://stormwater.pca.state.mn.us/index.php/Design_criteria_for_bioretention#Materials_specifications_-_filter_media) used and the presence or absence of amendments (http://stormwater.pca.state.mn.us/index.php/Soil_amendments_to_enhance_phosphorus_sorption). Soil mixes with more than 30 mg/kg phosphorus (P) content are likely to leach phosphorus and do not qualify for a water quality credit. If the soil phosphorus concentration is less than 30 mg/kg, the mass of phosphorus removed through filtration, in pounds, is given by

$$M_{TP_f} = 0.0000624\ (V_{total} - (V_{inf_b} + V_{inf_s} + V_U))\ EMC_{TP}\ R_{TP}$$

Information: Soil mixes C and D are assumed to contain less than 30 mg/kg of phosphorus and therefore do not require testing

Again, assuming the phosphorus content in the media is less than 30 milligrams per kilogram, the removal efficiency (R_{TP}) provided in the Stormwater Manual (http://stormwater.pca.state.mn.us/index.php/Phosphorus_credits_for_bioretention_systems_with_an_underdrain) is a function of the fraction of phosphorus that is in particulate or dissolved form, the depth of the media, and the presence or absence of soil amendments. For the purpose of calculating credits it can be assumed that TP in storm water runoff consists of 55 percent particulate phosphorus (PP) and 45 percent dissolved phosphorus (DP). The removal efficiency for particulate phosphorus is 80 percent. The removal efficiency for dissolved phosphorus is 20 percent if the media depth is 2 feet or greater. The efficiency decreases by 1 percent for each 0.1 foot decrease in media thickness below 2 feet. If a soil amendment is added to the BMP design, an additional 40 percent credit is applied to dissolved phosphorus. Thus, the overall removal efficiency, (R_{TP}), expressed as a percent removal of total phosphorus, is given by

$$R_{TP} = (0.8 * 0.55) + (0.45 * ((0.2 * (D_{MU_{max=2}})/2) + 0.40_{ifamendmentisused})) * 100$$

where

- the first term on the right side of the equation represents the removal of particulate phosphorus;
- the second term on the right side of the equation represents the removal of dissolved phosphorus; and
- $D_{MU_{max=2}}$ = the media depth above the underdrain, up to a maximum of 2 feet.

Example calculations for TSS and P

Three examples are included based on the extent of infiltration occurring in the BMP. For each of these examples, assume 2.75 acre-feet of water is delivered to a bioretention BMP from 1 acre of impervious surface, the TSS concentration in runoff is 54.5 milligrams per liter, and the total phosphorus concentration is 0.30 milligrams per liter.

Example 1: Bioinfiltration (no underdrain)
Assume the bioinfiltration practice is designed to capture 90 percent of annual runoff, or 2.475 acre-feet. Multiply this by the concentration (0.3 or 54.5), a conversion factor of 0.0000624 to convert into pounds, and 43560 square feet to convert to cubic feet.

TSS: (0.9*2.75)(54.5)(0.0000624)(43560) = 366.6 pounds
P: (0.9*2.75)(0.3)(0.0000624)(43560) = 2.02 pounds

Example 2: Biofiltration with lined sides and bottom (i.e. no infiltration)
Assume the bioinfiltration practice is designed to capture 90 percent of annual runoff, or 2.475 acre-feet. Assume 1 foot of media, Mix C, above the underdrain and an iron amendment is added. For TSS, the removal efficiency is 85 percent for the water that is captured by the BMP. Since media mix C is used, phosphorus will be removed by the BMP. Calculations must be made for particulate (PP) and dissolved phosphorus (DP). PP accounts for 55 percent of the total phosphorus (TP) and DP for 45 percent of the TP. The removal efficiency for PP is 0.80 (80%) for the water captured by the BMP. For DP, the removal efficiency is 0.20 (20 percent) times the media depth divided by 2 (1/2 or 0.5), plus 0.40 (40 percent, which accounts for the amendment).

TSS: (0.85*0.9*2.75)(54.5)(0.0000624)(43560) = 311.6 pounds
P

PP: (0.55*0.8*0.9*2.75)(0.3)(0.0000624)(43560) = 0.888 pounds
DP: ((0.2*0.5*+0.4)(0.45)(2.75)(43560)(0.3)(0.0000624)) = 0.454 pounds
TP: (0.888+0.454) = 1.342 pounds

Example 3: Biofiltration with unlined sides and bottom (i.e. some infiltration occurs)
To make this calculation, we need to know the percent of water that infiltrates and the percent that is captured by the underdrain. Note the volume infiltrated will need to be calculated using the methodology described above. To simplify the calculations in this example, assume 10 percent of the captured water infiltrates, while the remaining water goes to the underdrain.

TSS

Infiltrated: (0.9)(0.1)(43560)(2.75)(54.5)(0.0000624) = 36.7 pounds. Note this is 10 percent of the volume calculated in Example 1.
Filtered (underdrain): (0.85)(0.9)(0.9)(43560)(2.75)(54.5)(0.0000624) = 280.5 pounds. Note this is 90 percent of the TSS calculated in Example 2.
Total: 317.2 pounds

P

Infiltrated: (0.9)(0.1)(43560)(2.75)(0.3)(0.0000624) = 0.202 pounds. Note this is 10 percent of the volume calculated in Example 1.
Filtered (underdrain): This calculation is the same as for Example 2, corrected for only 90 percent of the volume being treated by filtration. (1.342)(0.9) = 1.208 pounds
Total: 1.410 pounds

Methods for calculating credits

This section provides specific information on generating and calculating credits from bioretention BMPS for volume, Total Suspended Solids (TSS) and Total Phosphorus (TP). Stormwater runoff volume and pollution reductions ("credits") may be calculated using one of the following methods:

1. Quantifying volume and pollution reductions based on accepted hydrologic models
2. The Simple Method and MPCA Estimator
3. MIDS Calculator
4. Quantifying volume and pollution reductions based on values reported in literature
5. Quantifying volume and pollution reductions based on field monitoring

Credits based on models

Warning: The model selected depends on your objectives. For compliance with the Construction Stormwater permit, the model must be based on the assumption that an instantaneous volume is captured by the BMP.

Users may opt to use a water quality model or calculator to compute volume, TSS and/or TP pollutant removal for the purpose of determining credits for bioretention. The available models described below are commonly used by water resource professionals, but are not explicitly endorsed or required by the Minnesota Pollution Control Agency. Furthermore, many of the models listed below cannot be used to determine compliance with the Construction Stormwater General permit since the permit requires the water quality volume to be calculated as an instantaneous volume (http://stormwater.pca.state.mn.us/index.php/III._STORMWATER_DISCHARGE_DESIGN_REQUIREMENTS#III.D._PERMANENT_STORMWATER_MANAGEMENT_SYSTEM).

Use of models or calculators for the purpose of computing pollutant removal credits should be supported by detailed documentation, including:

- Model name and version
- Date of analysis
- Person or organization conducting analysis
- Detailed summary of input data
- Calibration and verification information
- Detailed summary of output data

The following table lists water quantity and water quality models that are commonly used by water resource professionals to predict the hydrologic, hydraulic, and/or pollutant removal capabilities of a single or multiple stormwater BMPs. The table can be used to guide a user in selecting the most appropriate model for computing volume, TSS, and/or TP removal for bioretention BMPs. In using this table to identify models appropriate for bioretention, use the sort arrow on the table to select Infiltrator BMPs or Filter BMPs, depending on the type of bioretention BMP and the terminology used in the model.

Comparison of stormwater models and calculators. Additional information and descriptions for some of the models listed in this table can be found at this link (http://stormwater.pca.state.mn.us/index.php/Available_stormwater_models_and_selecting_a_model). Note that the Construction Stormwater General Permit (http://stormwater.pca.state.mn.us/index.php/III._STORMWATER_DISCHARGE_DESIGN_REQUIREMENTS#III.D._PERMANENT_STORMWATER_MANAGEMENT_SYSTEM) requires the water quality volume to be calculated as an instantaneous volume, meaning several of these models cannot be used to determine compliance with the permit.
Link to this table
Access this table as a Microsoft Word document: File:Stormwater Model and Calculator Comparisons table.docx.

Model name	BMP Category						Assess TP removal?	Assess TSS removal?	Assess volume reduction?	Comments
	Constructed basin BMPs	Filter BMPs	Infiltrator BMPs	Swale or strip BMPs	Reuse	Manu-factured devices				
Center for Neighborhood Technology Green Values National Stormwater Management Calculator (http://greenvalues.cnt.org/national/calculator.php)	X	X	X		X		No	No	Yes	Does not compute volume reduction for some BMPs, including cisterns and tree trenches.

	BMP Category									
Model name	**Constructed basin BMPs**	**Filter BMPs**	**Infiltrator BMPs**	**Swale or strip BMPs**	**Reuse**	**Manu-factured devices**	**Assess TP removal?**	**Assess TSS removal?**	**Assess volume reduction?**	**Comments**
CivilStorm (http://www.bentley.com/en-US/Products/CivilStorm/)							Yes	Yes	Yes	CivilStorm has an engineering library with many different types of BMPs to choose from. This list changes as new information becomes available.
EPA National Stormwater Calculator (http://www.epa.gov/nrmrl/wswrd/wq/models/swc/)	X		X		X		No	No	Yes	Primary purpose is to assess reductions in stormwater volume.
EPA SWMM (http://www.epa.gov/nrmrl/wswrd/wq/models/swmm/)	X		X		X		Yes	Yes	Yes	User defines parameter that can be used to simulate generalized constituents.
HydroCAD (http://www.hydrocad.net/)	X		X	X			No	No	Yes	Will assess hydraulics, volumes, and pollutant loading, but not pollutant reduction.
infoSWMM (http://www.innovyze.com/products/infoswmm/)	X		X		X		Yes	Yes	Yes	User defines parameter that can be used to simulate generalized constituents.
infoWorks ICM (http://www.innovyze.com/products/infoworks_icm/)	X	X	X	X			Yes	Yes	Yes	
i-Tree-Hydro (http://www.itreetools.org/hydro/index.php)			X				No	No	Yes	Includes simple calculator for rain gardens.
i-Tree-Streets (http://www.itreetools.org/streets/index.php)							No	No	Yes	Computes volume reduction for trees, only.

Model name	BMP Category: Constructed basin BMPs	Filter BMPs	Infiltrator BMPs	Swale or strip BMPs	Reuse	Manu-factured devices	Assess TP removal?	Assess TSS removal?	Assess volume reduction?	Comments
LSPC (http://www.epa.gov/athens/wwqtsc/html/lspc.html)	X		X	X			Yes	Yes	Yes	Though developed for HSPF, the USEPA BMP Web Toolkit can be used with LSPC to model structural BMPs such as detention basins, or infiltration BMPs that represent source control facilities, which capture runoff from small impervious areas (e.g., parking lots or rooftops).
MapShed (http://www.mapshed.psu.edu/overview.htm)	X	X	X	X			Yes	Yes	Yes	Region-specific input data not available for Minnesota but user can create this data for any region.
MCWD/MWMO Stormwater Reuse Calculator (http://minnehahacreek.org/sites/minnehahacreek.org/files/Stormwater%20Harvesting%20and%20Reuse%20Model_v2.0.xlsx)					X		Yes	No	Yes	Computes storage volume for stormwater reuse systems
Metropolitan Council Stormwater Reuse Guide Excel Spreadsheet (http://www.metrocouncil.org/Wastewater-Water/Planning/Water-Supply-Planning.aspx)					X		No	No	Yes	Computes storage volume for stormwater reuse systems. Uses 30-year precipitation data specific to Twin Cites region of Minnesota.
MIDS Calculator (http://stormwater.pca.state.mn.us/index.php/MIDS_calculator)	X	X	X	X	X	X	Yes	Yes	Yes	Includes user-defined feature that can be used for manufactured devices and other BMPs.

	BMP Category									
Model name	**Constructed basin BMPs**	**Filter BMPs**	**Infiltrator BMPs**	**Swale or strip BMPs**	**Reuse**	**Manu- factured devices**	**Assess TP removal?**	**Assess TSS removal?**	**Assess volume reduction?**	**Comments**
MIKE URBAN (SWMM or MOUSE) (http://www.mikebydhi.com/Products/Cities/MIKEURBAN.aspx)	X		X		X		Yes	Yes	Yes	User defines parameter that can be used to simulate generalized constituents.
P8 (http://wwwalker.net/p8/)	X		X	X		X	Yes	Yes	Yes	
PCSWMM (http://www.chiwater.com/Software/PCSWMM/)	X		X		X		Yes	Yes	Yes	User defines parameter that can be used to simulate generalized constituents.
PLOAD (http://water.epa.gov/scitech/datait/models/basins/framework.cfm#models)	X	X	X	X		X	Yes	Yes	No	User-defined practices with user-specified removal percentages.
PondNet (http://wwwalker.net/)	X						Yes	No	Yes	Flow and phosphorus routing in pond networks.
PondPack (http://www.bentley.com/en-US/Products/PondPack)	X		[				No	No	Yes	PondPack can calculate first-flush volume, but does not model pollutants. It can be used to calculate pond infiltration.
RECARGA (http://dnr.wi.gov/topic/stormwater/standards/recarga.html)			X				No	No	Yes	
SELECT (http://www.werf.org/i/c/Tools/SELECT.aspx)	X	X	X	X		X	Yes	Yes	Yes	User defines parameter that can be used to simulate generalized constituents.
SHSAM (https://shsam.barr.com/)						X	No	Yes	No	Several flow-through structures including standard sumps, and proprietary systems such as CDS, Stormceptors, and Vortechs systems
SUSTAIN (http://www.epa.gov/nrmrl/wswrd/wq/models/sustain/)	X	X	X	X	X		Yes	Yes	Yes	Categorizes BMPs into Point BMPs, Linear BMPs, and Area BMPs

Model name	BMP Category						Assess TP removal?	Assess TSS removal?	Assess volume reduction?	Comments
	Constructed basin BMPs	Filter BMPs	Infiltrator BMPs	Swale or strip BMPs	Reuse	Manu-factured devices				
SWAT (http://swat.tamu.edu/)	X	X	X				Yes	Yes	Yes	Model offers many agricultural BMPs and practices, but limited urban BMPs at this time.
Virginia Runoff Reduction Method (http://www.vwrrc.vt.edu/swc/Virginia%20Runoff%20Reduction%20Method.html)	X	X	X	X	X	X	Yes	No	Yes	Users input Event Mean Concentration (EMC) pollutant removal percentages for manufactured devices.
WARMF (http://www.epa.gov/athens/wwqtsc/html/warmf.html)	X	X					Yes	Yes	Yes	Includes agriculture BMP assessment tools. Compatible with USEPA Basins
WinHSPF (http://www.aquaterra.com/resources/hspfsupport/index.php)	X		X	X			Yes	Yes	Yes	USEPA BMP Web Toolkit available to assist with implementing structural BMPs such as detention basins, or infiltration BMPs that represent source control facilities, which capture runoff from small impervious areas (e.g., parking lots or rooftops).
WinSLAMM (http://winslamm.com/)	X	X	X	X			Yes	Yes	Yes	
XPSWMM (http://www.xpsolutions.com/software/xpswmm/)	X		X		X		Yes	Yes	Yes	User defines parameter that can be used to simulate generalized constituents.

The Simple Method and MPCA Estimator

The Simple Method is a technique used for estimating storm pollutant export delivered from urban development sites. Pollutant loads are estimated as the product of mean pollutant concentrations and runoff depths over specified periods of time (usually annual or seasonal). The method was developed to provide an easy yet reasonably accurate means of predicting the change in pollutant loadings in response to development. Ohrel (http://www.stormw

atercenter.net/Library/Practice/13.pdf) (2000) states: "In general, the Simple Method is most appropriate for small watersheds (<640 acres) and when quick and reasonable stormwater pollutant load estimates are required". Rainfall data, land use (runoff coefficients), land area, and pollutant concentration are needed to use the Simple Method. For more information on the Simple Method, see The Simple method to Calculate Urban Stormwater Loads (http://www.stormwatercenter.net/monitoring%20and%20assessment/simple%20meth/simple.htm) or The Simple Method for estimating phosphorus export.

Some simple stormwater calculators utilize the Simple Method (STEPL (http://it.tetratech-ffx.com/steplweb/models$docs.htm), Watershed Treatment Model (http://www.cwp.org/online-watershed-library/cat_view/65-tools/91-watershed-treatment-model)). The MPCA developed a simple calculator for estimating load reductions for TSS, total phosphorus, and bacteria. Called the **MPCA Estimator** (http://stormwater.pca.state.mn.us/index.php/Guidance_and_examples_for_using_the_MPCA_Estimator), this tool was developed specifically for complying with the MS4 General Permit TMDL annual reporting requirement (http://stormwater.pca.state.mn.us/index.php/MS4_PART_III.STORMWATER_POLLUTION_PREVENTION_PROGRAM_%28SWPPP%29#E._Discharges_to_Impaired_Waters_with_a_USEPA-Approved_TMDL_that_Includes_an_Applicable_WLA). The MPCA Estimator provides default values for pollutant concentration, runoff coefficients for different land uses, and precipitation, although the user can modify these and is encouraged to do so when local data exist. The user is required to enter area for different land uses and area treated by BMPs within each of the land uses. BMPs include infiltrators (e.g. bioinfiltration, infiltration basin, tree trench, permeable pavement, etc.), filters (biofiltration, sand filter, green roof), constructed ponds and wetlands, and swales/filters. The MPCA Estimator includes standard removal efficiencies for these BMPs, but the user can modify those values if better data are available. Output from the calculator is given as a load reduction (percent, mass, or number of bacteria) from the original estimated load.

Warning: The MPCA Estimator should not be used for modeling a stormwater system or selecting BMPs.

Because the MPCA Estimator does not consider BMPs in series, makes simplifying assumptions about runoff and pollutant removal processes, and uses generalized default information, it should only be used for estimating pollutant reductions from an estimated load. It is not intended as a decision-making tool.

Download MPCA Estimator here: File:MPCA Estimator.xlsx

A quick guide for the estimator is available Quick Guide: MPCA Estimator tab.

MIDS Calculator

The Minimal Impact Design Standards (MIDS) best management practice (BMP) calculator is a tool used to determine stormwater runoff volume and pollutant reduction capabilities of various low impact development (LID) BMPs. The MIDS calculator estimates the stormwater runoff volume reductions for various BMPs and annual pollutant load reductions for total phosphorus (including a breakdown between particulate and dissolved phosphorus) and total suspended solids (TSS). The calculator was intended for use on individual development sites, though capable modelers could modify its use for larger applications.

Minimal Impact Design Standards
for enhancing stormwater management in Minnesota

Download the MIDS Calculator

The MIDS calculator is designed in Microsoft Excel with a graphical user interface (GUI), packaged as a windows application, used to organize input parameters. The Excel spreadsheet conducts the calculations and stores parameters, while the GUI provides a platform that allows the user to enter data and presents results in a user-friendly manner.

Detailed guidance has been developed for all BMPs in the calculator, including biofiltration and bioinfiltration (http://stormwater.pca.state.mn.us/index.php/Requirements,_recommendations_and_information_for_using_bioretention_with_no_underdrain_BMPs_in_the_MIDS_calculator). An overview of individual input parameters and workflows is presented in the MIDS Calculator User Documentation (http://stormwater.pca.state.mn.us/index.php/User%E2%80%99s_Guide).

Credits based on reported literature values

A simplified approach to computing a credit would be to apply a reduction value found in literature to the pollutant mass load or concentration (EMC) of the bioretention device. Concentration reductions resulting from treatment can be converted to mass reductions if the volume of stormwater treated is known.

Designers may use the pollutant reduction values reported in this manual (http://stormwater.pca.state.mn.us/index.php/Information_on_pollutant_removal_by_BMPs) or may research values from other databases and published literature. Designers who opt for this approach should

- select the median value from pollutant reduction databases that report a range of reductions, such as from the International BMP Database (http://bmpdatabase.org/index.htm);
- select a pollutant removal reduction from literature that studied a bioretention device with site characteristics and climate similar to the device being considered for credits;
- review the article to determine that the design principles of the studied bioretention are close to the design recommendations for Minnesota, as described in this manual (http://stormwater.pca.state.mn.us/index.php/Design_criteria_for_bioretention) and/or by a local permitting agency; and
- give preference to literature that has been published in a peer-reviewed publication.

The following references summarize pollutant reduction values from multiple studies or sources that could be used to determine credits. Users should note that there is a wide range of monitored pollutant removal effectiveness in the literature. Before selecting a literature value, users should compare the characteristics of the monitored site in the literature against the characteristics of the proposed bioretention device, considering such conditions as watershed characteristics, bioretention sizing, soil infiltration rates, and climate factors.

- International Stormwater Best Management Practices (BMP) Database (http://bmpdatabase.org/Docs/2012%20Water%20Quality%20Analysis%20Addendum/BMP%20Database%20Categorical_SummaryAddendumReport_Final.pdf) Pollutant Category Summary Statistical Addendum: TSS, Bacteria, Nutrients, and Metals
  - Compilation of BMP performance studies published through 2011
  - Provides values for TSS, Bacteria, Nutrients, and Metals
  - Applicable to grass strips, bioretention, bioswales, detention basins, green roofs, manufactured devices, media filters, porous pavements, wetland basins, and wetland channels
- Effectiveness Evaluation of Best Management Practices for Stormwater Management in Portland, Oregon (https://www.portlandoregon.gov/bes/article/133994)
  - Appendix M contains Excel spreadsheet of structural and non-structural BMP performance evaluations
  - Provides values for sediment, nutrients, pathogens, metals, quantity, air purification, carbon sequestration, flood storage, avian habitat, aquatics habitat and aesthetics
  - Applicable to filters, wet ponds, porous pavements, soakage trenches, flow-through stormwater planters, infiltration stormwater planters, vegetated infiltration basins, swales, and treatment wetlands
- The Illinois Green Infrastructure Study (http://www.epa.state.il.us/green-infrastructure/docs/draft-final-report.pdf)
  - Figure ES-1 summarizes BMP effectiveness
  - Provides values for TN, TSS, peak flows / runoff volumes
  - Applicable to permeable pavements, constructed wetlands, infiltration, detention, filtration, and green roofs
- New Hampshire Stormwater Manual (http://des.nh.gov/organization/divisions/water/stormwater/manual.htm)
  - Volume 2, Appendix B summarizes BMP effectiveness
  - Provides values for TSS, TN, and TP removal
  - Applicable to basins and wetlands, stormwater wetlands, infiltration practices, filtering practices, treatment swales, vegetated buffers, and pre-treatment practices
- Design Guidelines for Stormwater Bioretention Facilities (http://aqua.wisc.edu/publications/PDFs/stormwaterbioretention.pdf). University of Wisconsin, Madison
  - Table 2-1 summarizes typical removal rates
  - Provides values for TSS, metals, TP, TKN, ammonium, organics, and bacteria
  - Applicable for bioretention
- BMP Performance Analysis (http://www.epa.gov/region1/npdes/stormwater/assets/pdfs/BMP-Performance-Analysis-Report.pdf). Prepared for US EPA Region 1, Boston MA.
  - Appendix B provides pollutant removal performance curves
  - Provides values for TP, TSS, and zinc
  - Pollutant removal broken down according to land use
  - Applicable to infiltration trench, infiltration basin, bioretention, grass swale, wet pond, and porous pavement
- Weiss, P.T., J.S. Gulliver and A.J. Erickson. 2005. The Cost and Effectiveness of Stormwater Management Practices: Final Report (http://www.lrrb.org/media/reports/200523.pdf)
  - Table 8 and Appendix B provides pollutant removal efficiencies for TSS and P
  - Applicable to wet basins, stormwater wetlands, bioretention filter, sand filter, infiltration trench, and filter strips/grass swales

Credits based on field monitoring

Field monitoring may be used to calculate stormwater credits in lieu of desktop calculations or models/calculators as described. Careful planning is HIGHLY RECOMMENDED before commencing a program to monitor the performance of a BMP. The general steps involved in planning and implementing BMP monitoring include the following.

1. Establish the objectives and goals of the monitoring.
   1. Which pollutants will be measured?
   2. Will the monitoring study the performance of a single BMP or multiple BMPs?
   3. Are there any variables that will affect the BMP performance? Variables could include design approaches, maintenance activities, rainfall events, rainfall intensity, etc.
   4. Will the results be compared to other BMP performance studies?
   5. What should be the duration of the monitoring period? Is there a need to look at the annual performance vs the performance during a single rain event? Is there a need to assess the seasonal variation of BMP performance?
2. Plan the field activities. Field considerations include:
   1. Equipment selection and placement
   2. Sampling protocols including selection, storage, delivery to the laboratory
   3. Laboratory services
   4. Health and Safety plans for field personnel
   5. Record keeping protocols and forms
   6. Quality control and quality assurance protocols
3. Execute the field monitoring
4. Analyze the results

The following guidance manuals have been developed to assist BMP owners and operators on how to plan and implement BMP performance monitoring.

Urban Stormwater BMP Performance Monitoring (http://water.epa.gov/scitech/wastetech/guide/stormwater/monitor.cfm)

Geosyntec Consultants and Wright Water Engineers prepared this guide in 2009 with support from the USEPA, Water Environment Research Foundation, Federal Highway Administration, and the Environment and Water Resource Institute of the American Society of Civil Engineers. This guide was developed to improve and standardize the protocols for all BMP monitoring and to provide additional guidance for Low Impact

Development (LID) BMP monitoring. Highlighted chapters in this manual include:

- Chapter 2: Designing the Program
- Chapters 3 & 4: Methods and Equipment
- Chapters 5 & 6: Implementation, Data Management, Evaluation and Reporting
- Chapter 7: BMP Performance Analysis
- Chapters 8, 9, & 10: LID Monitoring

Evaluation of Best Management Practices for Highway Runoff Control (NCHRP Report 565) (http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_565.pdf)

AASHTO (American Association of State Highway and Transportation Officials) and the FHWA (Federal Highway Administration) sponsored this 2006 research report, which was authored by Oregon State University, Geosyntec Consultants, the University of Florida, and the Low Impact Development Center. The primary purpose of this report is to advise on the selection and design of BMPs that are best suited for highway runoff. The document includes the following chapters on performance monitoring that may be a useful reference for BMP performance monitoring, especially for the performance assessment of a highway BMP:

- Chapter 4: Stormwater Characterization
  - 4.2: General Characteristics and Pollutant Sources
  - 4.3: Sources of Stormwater Quality data
- Chapter 8: Performance Evaluation
  - 8.1: Methodology Options
  - 8.5: Evaluation of Quality Performance for Individual BMPs
  - 8.6: Overall Hydrologic and Water Quality Performance Evaluation
- Chapter 10: Hydrologic Evaluation
  - 10.5: Performance Verification and Design Optimization

Investigation into the Feasibility of a National Testing and Evaluation Program for Stormwater Products and Practices (http://www.wef.org/uploadedFiles/Access_Water_Knowledge/Stormwater_and_Wet_Weather/Stormwater_PDFs/WEF-STEPP-White%20Paper_Final_02-06-14%282%29.pdf).

In 2014 the Water Environment Federation released this White Paper that investigates the feasibility of a national program for the testing of stormwater products and practices. The information contained in this White Paper would be of use to those considering the monitoring of a manufactured BMP. The report does not include any specific guidance on the monitoring of a BMP, but it does include a summary of the existing technical evaluation programs that could be consulted for testing results for specific products (see Table 1 on page 8).

Caltrans Stormwater Monitoring Guidance Manual (Document No. CTSW-OT-13-999.43.01) (http://www.dot.ca.gov/hq/env/stormwater/pdf/CTSW_OT_13_999.pdf)

The most current version of this manual was released by the State of California, Department of Transportation in November 2013. As with the other monitoring manuals described, this manual does include guidance on planning a stormwater monitoring program. However, this manual is among the most thorough for field activities. Relevant chapters include:

- Chapter 4: Monitoring Methods and Equipment
- Chapter 5: Analytical Methods and Laboratory Selection
- Chapter 6: Monitoring Site Selection
- Chapter 8: Equipment Installation and Maintenance
- Chapter 10: Pre-Storm Preparation
- Chapter 11: Sample Collection and Handling
- Chapter 12: Quality Assurance / Quality Control
- Chapter 13: Laboratory Reports and Data Review
- Chapter 15: Gross Solids Monitoring

Optimizing Stormwater Treatment Practices: A Handbook of Assessment and Maintenance (http://stormwaterbook.safl.umn.edu/)

This online manual was developed in 2010 by Andrew Erickson, Peter Weiss, and John Gulliver from the University of Minnesota and St. Anthony Falls Hydraulic Laboratory with funding provided by the Minnesota Pollution Control Agency. The manual advises on a four-level process to assess the performance of a Best Management Practice, involving:

- Level 1: Visual Inspection
- Level 2: Capacity Testing
- Level 3: Synthetic Runoff Testing
- Level 4: Monitoring
- Level 1 activities do not produce numerical performance data that could be used to obtain a stormwater management credit. BMP owners and operators who are interested in using data obtained from Levels 2 and 3 should consult with the MPCA or other regulatory agency to determine if the results are appropriate for credit calculations. Level 4, Monitoring, is the method most frequently used for assessment of the performance of a BMP.

Use these links to obtain detailed information on the following topics related to BMP performance monitoring:

- Water Budget Measurement (http://stormwaterbook.safl.umn.edu/developing-assessment-program/water-budget-measurement)
- Sampling Methods (http://stormwaterbook.safl.umn.edu/developing-assessment-program/sampling-methods)

- Analysis of Water and Soils (http://stormwaterbook.safl.umn.edu/developing-assessment-program/analysis-water-and-soils)
- Data Analysis for Monitoring (http://stormwaterbook.safl.umn.edu/assessment-programs/data-analysis)

Other pollutants

In addition to TSS and phosphorus, bioretention BMPs can reduce loading of other pollutants. According to the International Stormwater Database (http://www.bmpdatabase.org/Docs/Simple%20Summary%20BMP%20Database%20July%202012%20Final.pdf), studies have shown that bioretention BMPs are effective at reducing concentrations of pollutants, including metals, and bacteria. A compilation of the pollutant removal capabilities from a review of literature are summarized below.

Relative pollutant reduction from bioretention systems for metals, nitrogen, bacteria, and organics.
Link to this table

Pollutant	Constituent	Treatment capabilities[1]
Metals[2]	Cadmium, Chromium, Copper, Zinc, Lead	High
Nitrogen[2]	Total nitrogen, Total Kjeldahl nitrogen	Low/medium
Bacteria[2]	Fecal coliform, e. coli	High
Organics	Petroleum hydrocarbons[3], Oil/grease[4]	High

[1] Low: < 30%; Medium: 30 to 65%; High: >65%

[2] International Stormwater Database (http://bmpdatabase.org/Docs/2012%20Water%20Quality%20Analysis%20Addendum/BMP%20Database%20Categorical_SummaryAddendumReport_Final.pdf), (2012)

[3] LeFevre et al., (2012)

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- Bioretention
  - Bioretention terminology (including types of bioretention)
  - Overview for bioretention
  - Design criteria for bioretention
  - Construction specifications for bioretention
  - Operation and maintenance of bioretention
  - Cost-benefit considerations for bioretention
  - Calculating credits for bioretention
  - Soil amendments to enhance phosphorus sorption
  - Summary of permit requirements for bioretention
  - Supporting material for bioretention
  - External resources for bioretention
  - References for bioretention
  - Requirements, recommendations and information for using bioretention with no underdrain BMPs in the MIDS calculator
  - Requirements, recommendations and information for using bioretention with an underdrain BMPs in the MIDS calculator

- Calculating credits
  - Calculating credits for bioretention
  - Calculating credits for infiltration basin
  - Calculating credits for infiltration trench
  - Calculating credits for permeable pavement
  - Calculating credits for green roofs
  - Calculating credits for sand filter
  - Calculating credits for stormwater ponds
  - Calculating credits for stormwater wetlands
  - Calculating credits for iron enhanced sand filter
  - Calculating credits for swale
  - Calculating credits for tree trenches and tree boxes
  - Calculating credits for stormwater and rainwater harvest and use/reuse